

## VISUAL DOMINANCE IN THE PIGEON

A. RANDICH,<sup>1</sup> R. M. KLEIN, AND V. M. LoLORDO

DALHOUSIE UNIVERSITY

In Experiment 1, three pigeons were trained to obtain grain by depressing one foot treadle in the presence of a 746-Hertz tone stimulus and by depressing a second foot treadle in the presence of a red light stimulus. Intertrial stimuli included white light and the absence of tone. The latencies to respond on auditory element trials were as fast, or faster, than on visual element trials, but pigeons always responded on the visual treadle when presented with a compound stimulus composed of the auditory and visual elements. In Experiment 2, pigeons were trained on the auditory-visual discrimination task using as trial stimuli increases in the intensity of auditory or visual intertrial stimuli. Again, pigeons showed visual dominance on subsequent compound stimulus test trials. In Experiment 3, on compound test trials, the onset of the visual stimulus was delayed relative to the onset of the auditory stimulus. Visual treadle responses generally occurred with delay intervals of less than 500 milliseconds, and auditory treadle responses generally occurred with delay intervals of greater than 500 milliseconds. The results are discussed in terms of Posner, Nissen, and Klein's (1976) theory of visual dominance in humans.

*Key words:* visual dominance, auditory-visual discrimination, food, stimulus compound-ing, pigeons

The concept of selective attention is used to explain a variety of data in both the human information processing and animal learning literatures. In spite of this commonality, the two fields differ with respect to both research methodologies and theoretical explanations of selective attention phenomena. Human studies typically ask how instructional and stimulus variables influence steady-state performance, and emphasize the concept of limited information processing resources and the strategic control over the use of these resources (*cf.* Posner and Snyder, 1975). Animal studies typically ask how stimulus variables and prior histories of reinforcement affect the learning of associations between stimuli and responses, and stress factors such as stimulus salience and the "information" value of stimulus events (*cf.* Kamin, 1969; Mackintosh, 1975).

Consideration of these dichotomous literatures suggests a question. Are the mechanisms underlying the phenomena of selective attention in animals and man truly different, or are the apparent differences merely an artifact of the interests and paradigms that characterize the two fields? Surely, no answer will be forthcoming, and no real comparisons will be possible until attentional processes in animals and man are studied under analogous conditions.

In the following experiments, a technique introduced by Colavita (1974) to study human selective attention was applied to pigeons, in a search for similar effects in the two species. Colavita trained human subjects to respond on one key to a visual stimulus and on another key to an auditory stimulus. When reaction times were virtually equivalent on auditory and visual element trials, a compound stimulus composed of both elements was presented unexpectedly to the subject. Ten subjects responded on the visual key on 49 of 50 compound test trials, and some reported that they did not even hear the auditory stimulus on compound test trials.

In the present experiments, pigeons were trained to perform a similar auditory-visual discrimination task by depressing two differ-

<sup>1</sup>This research was supported by grants from the National Research Council of Canada to V. M. LoLordo and R. M. Klein. Reprints may be obtained from A. Randich, Department of Psychology, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1. We gratefully acknowledge P. Urcuioli, W. J. Jacobs, K. Shapiro, W. K. Honig, J. Willner, and T. Whalen for their stimulating discussions on this research, and J. Lord for the preparation of this manuscript. Portions of this paper were presented by A. Randich at the APA convention in San Francisco, 1977.

ent foot treadles to obtain grain. When response latency measures indicated that the performances of the auditory and visual treadle responses were asymptotic, the pigeons were given compound stimulus test trials similar to those used by Colavita (1974).

## EXPERIMENT I

### METHOD

#### *Subjects*

Three experimentally naive White King pigeons, obtained from the Palmetto Pigeon Plant in Sumter, South Carolina, were food-deprived to 80% of their free-feeding weights and maintained at this level throughout the experiment. Water was freely available in the home cages.

#### *Apparatus*

Training was conducted in a 42-cm by 28-cm by 30-cm chamber. Two 9-cm by 7-cm foot-treadles were attached to wooden bars and located near the right and left edges of the front aluminum wall. The treadles were tilted down from the wall at a 30° angle to a cardboard-backed grid floor. The lower edge of each treadle was 3.5 cm from the floor when the treadle was not depressed. Approximately 0.49 N downward force on the treadle was required to activate the response microswitch. A treadle response was used because previous studies conducted in this laboratory on stimulus control of food-reinforced responding in pigeons have used this response (*cf.* Foree and LoLordo, 1973). A 5-cm by 4.5-cm grain magazine was located between the two treadles on the front wall and was illuminated when grain was available.

A speaker mounted on the front portion of the left wall produced a 746-Hz tone, which raised the sound level in the chamber from 60 to 83 dB (scale A; 20  $\mu$ N/m<sup>2</sup>). Visual stimuli were mounted above a translucent white Perspex ceiling. Four red 120-V Christmas tree bulbs made up the red-light stimulus, and two similar white bulbs served as the white-light stimulus during the intertrial interval (ITI).

The experimental chamber was contained in a ventilated, sound-attenuated box, with ventilation fans providing masking noise (60 dB, scale A). All programming and recording were controlled by electromechanical relay equipment located in an adjacent room.

#### *Procedure*

*Training.* In the first session, pigeons were trained to eat from the grain magazine. They were then trained to depress the right treadle in the presence of the red-light stimulus, and to depress the left treadle in the presence of the tone stimulus. In each case, reinforcement consisted of a 3-sec access to grain. An equal number of reinforcements were delivered in the presence of the tone and light stimuli during this training period.

An ITI, during which a white-light stimulus was present, was introduced following each reinforcement and gradually increased in duration to a terminal value of 15 sec. Concurrently, the durations of the tone and red-light discriminative stimuli were gradually reduced to a terminal value of 5 sec.

The final training schedule consisted of a 15-sec ITI during which the white houselights were illuminated. A response on either treadle during the ITI caused a brief darkening (160 msec) of the chamber and extended the ITI for 15 sec from the time of the response. The brief darkening of the chamber produced by a response during the ITI served as a feedback stimulus to facilitate acquisition of the discrimination. If 15 sec elapsed without a response, a 5-sec trial period began. Either the red houselight or the tone was presented. A response on the correct treadle, *e.g.*, right treadle during the red light, immediately terminated the stimulus, produced 3 sec access to grain, and then reinstated the ITI conditions. A response on the incorrect treadle, *e.g.*, right treadle during the tone, immediately terminated the stimulus and reinstated the ITI. If no response occurred during the 5-sec trial period, the ITI was reinstated.

Thirty tone and 30 red-light trials were presented on a random basis in each session, and training continued until the pigeon responded correctly on every trial in a session. Response latencies during tone and light trials were recorded during the following three days.

*Testing.* The test sessions began with a brief warmup period during which the training conditions were in effect for five trials. During the next 80 trials, 16 compound stimulus test trials, composed of simultaneous onset of the tone and red-light stimuli, were interspersed among element trials at a rate of two compound trials for every 10 trials. Responses on

either the auditory or visual treadle during compound test trials were reinforced with 3 sec access to grain. The treadle on which the pigeon responded and the latency to respond were recorded on all trials in the test session. Analyses of variance were performed on auditory and visual response latencies for each pigeon. The level of rejection was set at  $p < 0.05$ .

### RESULTS

All pigeons acquired the auditory-visual discrimination within 20 sessions, although the extensive shaping procedure precluded any assessment of differential acquisition of the response in the presence of the two elements. ITI responses rarely occurred (range 2 to 7 on the final day of baseline training).

Figure 1 presents histograms of response latencies on auditory and visual element trials on the final day of baseline training (upper panels) and during the test session (middle panels) for these pigeons. Subject P1 responded significantly faster on auditory element trials than on visual element trials during the test session. Response latencies on auditory and visual element trials were not significantly different for either Subject P2 or P3 during the test session. The bottom panels of Figure 1

present histograms of response latencies during compound test trials in the test session as a function of the treadle on which the pigeons responded. Each pigeon responded on the visual treadle on every compound test trial (16/16), and response latencies on compound test trials were generally comparable to those obtained on visual element trials, although Subject P1 responded consistently more slowly on compound trials than on visual element trials.

### EXPERIMENT II

One possible explanation of the visual dominance effect obtained in Experiment I is that a pigeon's choice of the visual treadle during compound stimulus test trials reflects stimulus generalization decrement. In the training phase, visual element trials consisted of termination of the visual ITI stimulus (white light) and onset of the red trial stimulus. An auditory element trial consisted of onset of the tone trial stimulus in the presence of the visual ITI stimulus. In the test phase, the compound stimulus test trials consisted of simultaneous onset of the red-light stimulus and the tone stimulus, but in the absence of the

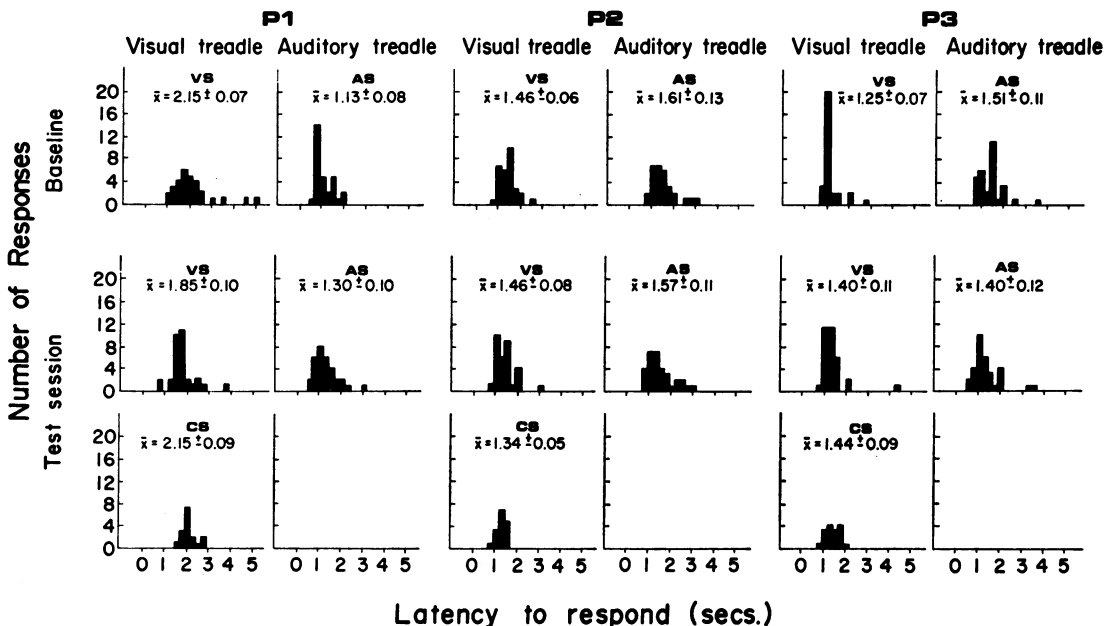


Fig. 1. Histograms of response latencies for Subjects P1, P2, and P3 in Experiment I during (1) auditory and visual trials on the final day of baseline training (upper panels), (2) auditory and visual trials during the test session (middle panels), and (3) compound test trials (lower panels), as a function of the treadle on which the pigeon responded. The mean response latency and standard error of the mean are denoted in each panel.

visual ITI stimulus. The absence of the visual ITI stimulus on compound stimulus test trials may make such trials more like the visual element trials (absence of visual ITI stimulus) than like auditory element trials (presence of the visual ITI stimulus). Less stimulus generalization decrement between visual element trials and compound trials than between auditory element trials and compound trials might then account for the visual dominance effect.

Experiment II tested a stimulus generalization decrement account of the visual dominance effect by presenting both auditory and visual ITI stimuli, and using increases in the intensity of such stimuli as trial stimuli. Thus, pigeons were required to perform an intensity discrimination on both auditory and visual element trials, and compound stimulus test trials involved simultaneous increases in the intensity of both auditory and visual ITI stimuli, thereby eliminating the asymmetrical relation between element and compound trials of the first experiment.

#### METHOD

##### *Subjects*

Two experimentally naive White King pigeons served; all other conditions were as described in Experiment I.

##### *Apparatus*

The apparatus was as described in Experiment I. The visual ITI stimulus was produced by overhead white houselights (0.27 candelas/m<sup>2</sup>) and the visual trial stimulus was produced by increasing the intensity of the overhead white houselights from 0.27 candelas/m<sup>2</sup> to 8.57 candelas/m<sup>2</sup>. The auditory ITI stimulus was a 746-Hz tone presented at 70 dB (A scale, SPL), and the auditory trial stimulus was produced by increasing the intensity of the 746-Hz tone from 70 dB to 80 dB (scale A, SPL).

##### *Procedure*

The basic training procedure was as described in Experiment I. The final training schedule consisted of a 15-sec ITI, during which both a 746-Hz tone (70 dB) and the overhead white houselights (0.27 candelas/m<sup>2</sup>) were on. A response on either treadle during the ITI caused a brief (160 msec) darkening of the chamber and a brief (160 msec) cessation of the tone, to equate modalities for the feedback stimuli. If 15 sec elapsed without a

response, a 5-sec trial period began in which either the intensity of the tone was increased from 70 to 80 dB, or the intensity of the white light was increased from 0.27 to 8.57 candelas/m<sup>2</sup>. For Subject P4, the right treadle was designated as the visual treadle and the left treadle as the auditory treadle. For Subject P5, the right treadle was designated as the auditory treadle and the left treadle as the visual treadle. A response on the appropriate treadle immediately terminated the stimulus (*i.e.*, reinstated the ITI stimulus) and produced 3 sec access to grain. A response on the inappropriate treadle immediately terminated the stimulus and reinstated the ITI conditions. If no response occurred during the 5-sec trial period, the ITI conditions were reinstated.

The test procedure was as described in Experiment I. Compound stimulus test trials were composed of simultaneous increases in the intensities of the visual and auditory ITI stimuli.

#### RESULTS

Subject P4 met the baseline criterion of 100% correct responses in 25 sessions. Subject P5 did not meet the baseline criterion of 100% correct responses in 36 sessions, but responded on an average of 83% of visual element trials and 90% of auditory element trials over the last 15 days of training, and then was tested.

Figure 2 presents histograms of response latencies on auditory and visual element trials on the final day of baseline training (upper panels) and during the test session (middle panels) for each pigeon. Both pigeons had shorter mean latencies to respond on auditory element trials than on visual element trials during the test session, although these differences were not significant. Subject P5 responded on 91% of the auditory element trials and 84% of the visual element trials in the test session; these percentages were comparable to those observed over the last 15 days of baseline training. The bottom panels of Figure 2 present histograms of response latencies during compound test trials as a function of the treadle on which the pigeons responded. Each pigeon responded on 15 of 16 compound stimulus test trials, and all responses were on the "visual treadle". Response latencies on compound test trials were comparable to those obtained on element trials.

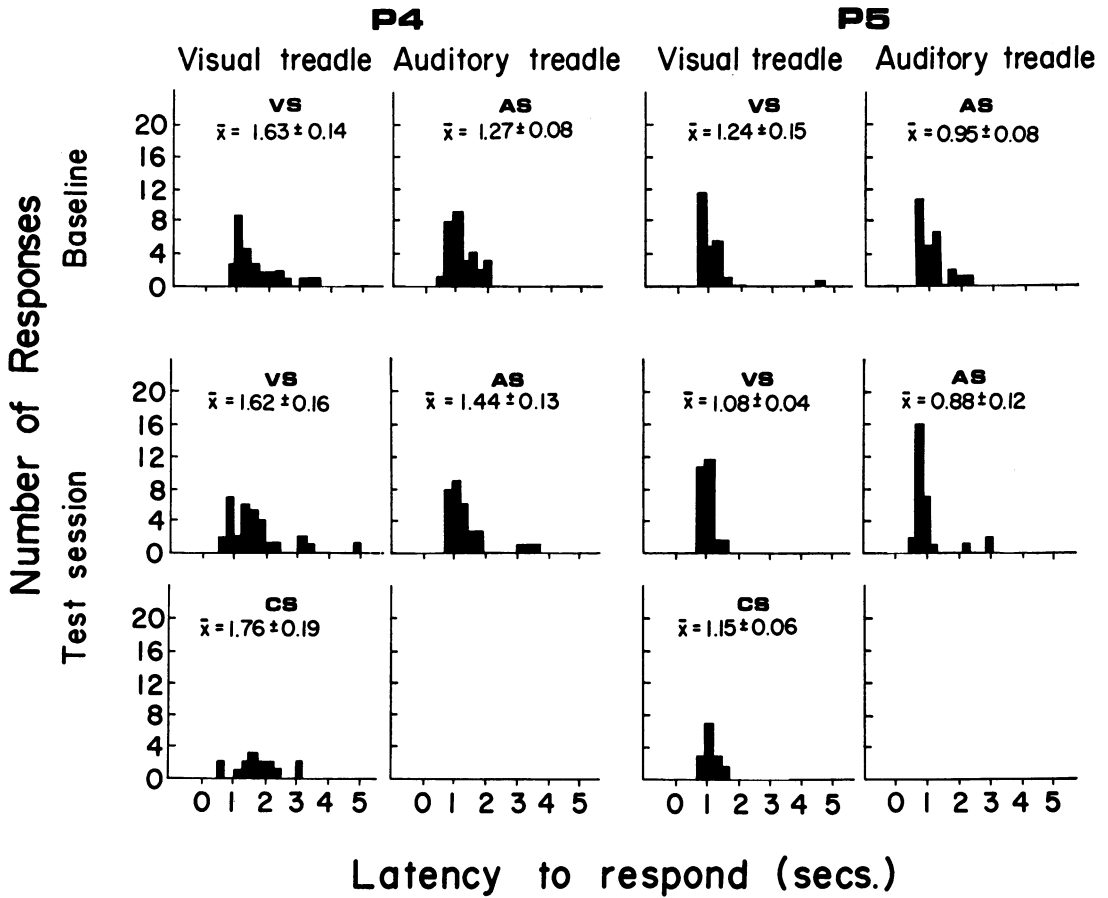


Fig. 2. Histograms of response latencies for Subjects P4 and P5 in Experiment II during (1) auditory and visual trials on the final day of baseline training (upper panels), (2) auditory and visual trials during the test session (middle panels), and (3) compound test trials (lower panels), as a function of the treadle on which the pigeon responded. The mean response latency and standard error of the mean are denoted in each panel.

### EXPERIMENT III

In Experiment III, the potency of the visual dominance effect was measured by delaying the onset of the visual stimulus relative to the onset of the auditory stimulus during "compound" stimulus test trials.

#### Subjects

The three pigeons used in Experiment I served.

#### Apparatus

The apparatus was as described in Experiment I.

#### Procedure

On the day following the test session of Experiment I, each pigeon received a similar

session, except that during compound trials, the onset of the visual stimulus was delayed relative to the onset of the auditory stimulus. The delay intervals were 0, 83, 166, 249, 333, 416, 500, 583, 666, 749, and 833 msec. For example, with a 500-msec delay interval the auditory stimulus was presented for 500 msec in the presence of the white ITI stimulus as on a normal auditory element trial. After 500 msec of auditory stimulus presentation, the red-light stimulus was compounded with the auditory stimulus, and the white ITI stimulus terminated. Compound trials were interspersed among element trials at the rate of two per 10 trials, and the various delays were presented *via* the method of limits using both ascending and descending sequences. Testing was conducted over a two-day period. Four compound trials were presented at each delay in-

interval to all pigeons except P3. Testing was not completed because P3 stopped responding on the third pass through the delay intervals. As in Experiment I, auditory or visual treadle responses during compound test trials were reinforced with 3 sec access to grain.

### RESULTS

Figure 3 presents the results of the delay manipulation for these pigeons. Response latency was calculated as the time from auditory stimulus onset to a treadle response. All pigeons continued to respond on the visual treadle during compound test trials in which the delay to visual stimulus onset was shorter than 500 msec. In general, Figure 3 shows that the latency to respond on such trials was increased only by the amount of the delay to visual stimulus onset. Subtracting the amount of delay to visual stimulus onset from the latency to respond on the visual treadle at each of these delay intervals yields response latencies (C/V) nearly equal to those obtained on visual element trials (V). Thus, pigeons were responding to visual stimulus onset and response latencies were not altered by prior auditory stimulus onset. When the delay to visual stimulus onset on compound test trials was longer than approximately 500 msec, the pigeons responded on the auditory treadle. Response latencies on such trials were consistently faster than those obtained on auditory element trials (compare A to C/A).

### GENERAL DISCUSSION

Treadle responding by pigeons trained on an auditory-visual discrimination task was controlled by the visual stimulus when it was presented in compound with the auditory stimulus. This visual dominance effect on compound test trials prevailed even when the onset of the visual stimulus was delayed relative to the onset of the auditory stimulus. These effects are unlikely to be due to differences between latencies to respond on auditory and visual element trials during training or testing. Response latencies on auditory element trials were either equivalent to, or shorter than, latencies on visual element trials. Indeed, if performance on element trials represents some measure of response strength, then Subjects P2 and P3 (Experiment I) and Subjects P4 and P5 (Experiment II) would

have been expected to respond on the auditory treadle on approximately 50% of compound trials, and Subject P1 (Experiment I) should have responded on the auditory treadle on virtually all the compound test trials. By contrast, all subjects responded exclusively to the visual treadle. Moreover, the choice data of Subject P1 (Experiment I), for which auditory element response latencies were significantly shorter than visual element response latencies, renders implausible the argument that the other birds showed visual dominance because their response latencies on visual element trials were at a "floor", and thus could not reveal greater response strength to the visual than to the auditory element.

Finally, it is unlikely that the visual dominance effect obtained in Experiment I was a result of greater stimulus generalization decrement between auditory element trials and compound trials than between visual element trials and compound trials. Experiment II showed that the same visual dominance effect occurred on compound stimulus trials that involved simultaneous increases in the intensity of auditory and visual ITI stimuli.

The present findings parallel those obtained by Colavita (1974) in a human reaction-time experiment, and, more recently, by Bushnell and Weiss (1977) in a stimulus-compounding experiment with rats. In the latter study, rats trained to respond for intermittent food reinforcement in a two-lever, auditory-visual discrimination task responded at a much higher rate on the light-correlated lever than on the tone-correlated lever during compound stimulus presentations. Similar effects had been reported previously by Miller (1973) and Meltzer and Masaki (1973). Furthermore, Bushnell and Weiss showed that decreasing the intensity of the light element of the compound tended to decrease the overall response rate, but had no marked effect on the distribution of responding on the two levers, *i.e.*, the rats continued to favor the light-correlated lever. Bushnell and Weiss also reported that presentation of the light to rats engaged in tone-correlated responding immediately produced a switch in the locus of responding from the tone lever to the light lever. In contrast, presentation of the tone to rats engaged in light-correlated responding produced no change in the locus of responding. The similarity between the effects observed by Bushnell and Weiss with

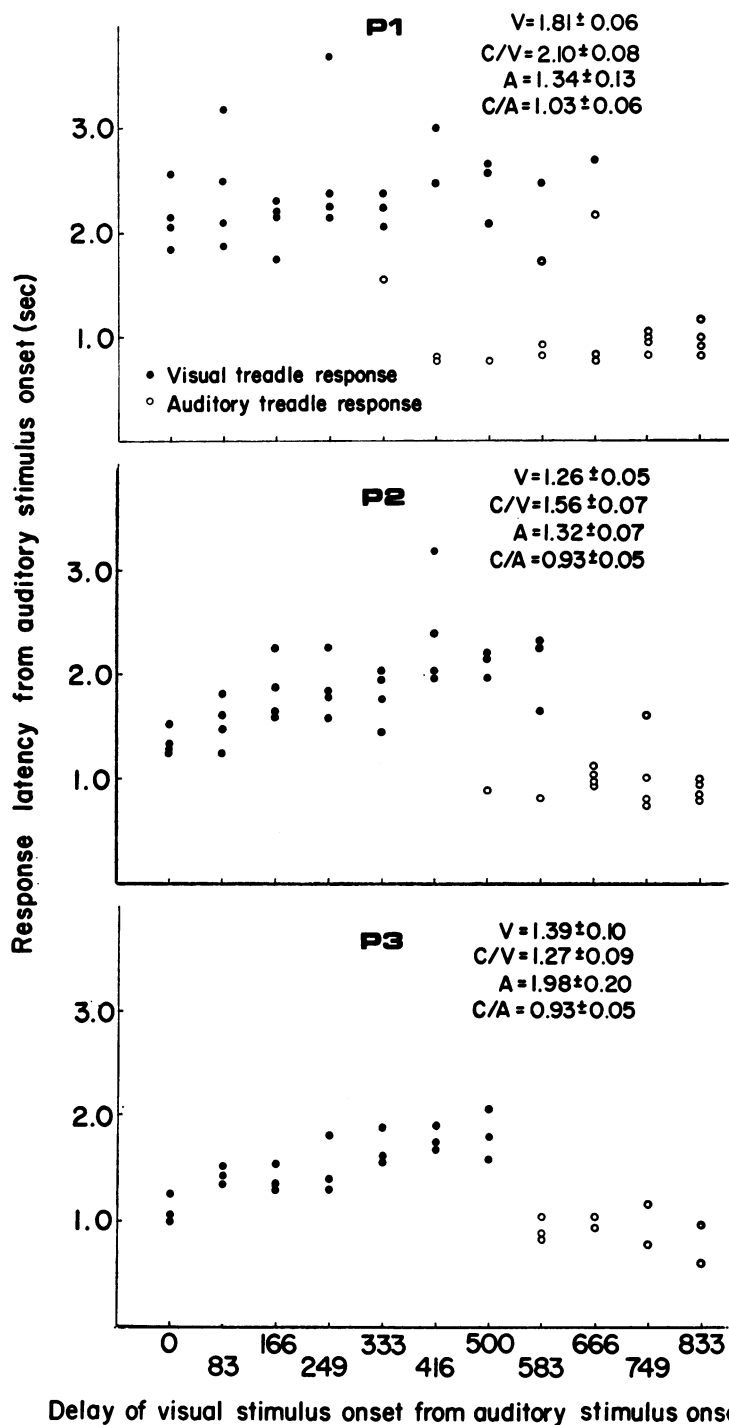


Fig. 3. Scatter plots of response latencies for subjects in Experiment III on compound test trials at each delay interval. Filled circles represent visual treadle responses and open circles represent auditory treadle responses. The mean response latency and standard error of the mean are also denoted for (1) visual (V) and auditory (A) trials during the test sessions, and (2) compound test trials on which the pigeons responded on either the auditory (C/A) or the visual (C/V) treadle. The C/V score was calculated by taking a mean of each visual treadle response latency on a compound test trial minus the delay to visual stimulus onset.

rats and the visual dominance effect obtained in the present study with pigeons suggests that a common mechanism may underlie both of these phenomena. It is interesting to note, however, that Bushnell and Weiss obtained additive summation of response rates during compound stimulus test periods. In the present experiments, there was no evidence of additive summation of response latencies during the compound stimulus test trials of Experiments I and II. That is, latencies on compound trials were not shorter than latencies on element trials. Colavita (1974) also obtained no evidence of additive summation of response latencies, or redundancy gain, during compound stimulus test trials in a similar design. Perhaps this discrepancy reflects the differences in response measures (response rate *versus* latency to respond) and in procedure (free-operant *versus* discrete-trial; cf. Mackintosh, 1974).

Similar visual dominance effects have also been reported with humans. Visual information often dominates information from other sensory modalities in judgements concerning the presence and location of objects (Gibson, 1933; Pick, Warren, and Hay, 1969) as well as in the performance of memorial and speeded response tasks (Colavita, 1974; Klein and Posner, 1974). There is no universally accepted explanation of visual dominance in humans, although Posner, Nissen, and Klein (1976) recently emphasized limited information processing resources and the subject's strategic control over the use of these resources. According to their view, visual stimuli are inferior to stimuli from other modalities in their capacity to alert (cf. Posner, 1975) central attention mechanisms. In the absence of remedial measures, this deficiency in visual alerting results in frequently missed visual signals. As a consequence, humans compensate for this deficiency by selectively attending to visual stimuli. This attentional strategy produces the visual dominance effect observed during compound stimulus presentations, where one of the elements of the compound is visual. How this model might be related to the data obtained in the present experiment is less clear. For instance, in Experiment III the latency to respond on the visual treadle during delayed compound test trials was increased only by the amount of the delay interval up to 500 msec. The pigeons were ap-

parently responding to visual stimulus onset and were not affected by prior onset of an auditory stimulus that signalled a conflicting or incompatible response. Responses that did occur on the auditory treadle during delayed compound trials, *i.e.*, at delay intervals longer than 500 msec, were consistently faster than responses on auditory element trials. This pattern of results is exactly opposite of that predicted by Posner *et al.*'s (1976) model for humans, and suggests that visual stimuli have automatic alerting effects for pigeons, similar to the alerting effects that nonvisual stimuli are postulated to have for humans. Thus, a strategic bias to compensate for poor visual alerting would seem unnecessary to account for the present data obtained with pigeons, although both pigeons and humans show the same visual dominance effect.

On the other hand, it is worthwhile to consider whether simultaneous or near-simultaneous onset of auditory and visual stimuli results in a masking effect. Such an effect was observed by Colavita (1974). Many subjects reported either that they had not heard the auditory stimulus during compound test trials, or that they realized the auditory stimulus had been present only after a trial had terminated. Colavita (1974) interpreted these reports as additional evidence supporting the notion that central attentional mechanisms can process information from only one modality at a time, *i.e.*, visual followed by auditory, when short-duration stimuli are presented simultaneously. Unfortunately, the present experiments had no additional, independent response measure that might have supplied information about a possible masking effect. Further experiments are needed to examine this possibility.

In a conceptually similar experiment, Foree and LoLordo (1973) trained pigeons to depress a treadle in the presence of an auditory-visual compound stimulus (red light and tone) either to obtain grain or to avoid electric shock. Subsequently, element tests revealed that the visual element primarily controlled responding in the appetitive condition, whereas the auditory element primarily controlled responding in the shock-avoidance condition. Foree and LoLordo concluded that the relative control exerted by the elements of an auditory-visual compound stimulus depends on the nature of the reinforcer. Such a notion



predicts that pigeons trained to perform an auditory-visual discrimination task to avoid electric shock would show auditory dominance on compound stimulus test trials. We have attempted to conduct this experiment, but to date have been unable to train pigeons to an adequate level of performance for proper testing of such a notion.

### REFERENCES

- Bushnell, M. C. and Weiss, S. J. The effect of reinforcement differences on choice and response distribution during stimulus compounding. *Journal of the Experimental Analysis of Behavior*, 1977, 27, 351-362.
- Colavita, F. B. Human sensory dominance. *Perception and Psychophysics*, 1974, 16, 409-412.
- Foree, D. D. and LoLordo, V. M. Attention in the pigeon: The differential effect of food getting vs. shock avoidance procedures. *Journal of Comparative and Physiological Psychology*, 1973, 85, 551-558.
- Gibson, J. J. Adaptation, after-effect and contrast in the perception of curved lines. *Journal of Experimental Psychology*, 1933, 16, 1-31.
- Kamin, L. J. Predictability, surprise, attention and conditioning. In B. A. Campbell and R. M. Church (Eds), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969. Pp. 279-296.
- Klein, R. M. and Posner, M. I. Attention to visual and kinesthetic components of skills. *Brain Research*, 1974, 71, 401-411.
- Mackintosh, N. J. *The psychology of animal learning*. London: Academic Press, 1974.
- Mackintosh, N. J. A theory of attention: Variations in the associability of stimuli with reinforcement. *Psychological Review*, 1975, 82, 276-298.
- Meltzer, D. and Masaki, M. A. Measures of stimulus control and stimulus dominance. *Bulletin of the Psychonomic Society*, 1973, 1, 28-30.
- Miller, L. Compounding of discriminative stimuli that maintain responding on separate levers. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 57-72.
- Pick, H. L., Warren, D. H., and Hay, J. C. Sensory conflict in judgements of spatial direction. *Perception and Psychophysics*, 1969, 6, 203-205.
- Posner, M. I. Psychobiology of attention. In M. Gazzaniga and C. Blakemore (Eds), *Handbook of psychobiology*. New York: Academic Press, 1975. Pp. 441-480.
- Posner, M. I., Nissen, M. J., and Klein, R. M. Visual dominance: An information-processing account of its origins and significance. *Psychological Review*, 1976, 83, 157-171.
- Posner, M. I. and Snyder, C. R. R. Attention and cognitive control. In R. L. Solso (Ed), *Information processing and cognition: the Loyola symposium*. Hillsdale, New Jersey: Erlbaum, 1975. Pp. 55-85.

Received 29 November 1977.

(Final acceptance 28 February 1978.)